System development for a large-scale astrophysical neutrinos observatory*

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We report on R & D activity for a km-scale detector system that will be capable of detecting Cherenkov light resulting from interactions of TeV neutrinos from potential astrophysical sources. The effort is based on a novel and comprehensive system concept which provides flexibility in array geometry, resistance to single-point-failure, and uncompromised data quality.

There are four broad issues which have influenced our approach: (1) small S/N ratio, (2) energy measurement, (3) background rejection, and (4) pattern recognition/track reconstruction. All these factors lead to the notion that the strength of the scientific results will depend critically on the quality of the primary data. This conclusion has had a major impact on the definition of the tasks we plan to undertake, e.g., the decision to employ sophisticated electronic devices at the detector level — digital optical modules (DOM) and local substring modules (LSM), which are to be embedded at the system level in a highly autonomous decentralized architecture of two candidate topologies.

At the detector level, we have chosen to develop the DOM based on an analog transient waveform recorder (ATWR) IC technical approach developed at LBNL. The advantages are: absence of ultra-high speed clocks and memory, low power dissipation (10 mW), excellent intrinsic S/N ratio (9 bits), excellent analog bandwidth (300 MHz), easily adjustable sample rate (0.3-3 GHz), easy calibration of sample rate, automatic simultaneous anode and dynode(s) wave form capture, automatic simultaneous clock phase capture for ns time resolution, conventional 1.2 μm CMOS IC technology, and easy integration with conventional IC components. In a new version called the transient waveform digitizer (TWD), a set of improvements will be implemented. The most significant one we envisage is the incorporation of an internal ADC capability based on a common-ramp Wilkinson technique, such that all samples of a given channel are digitized in parallel.

Based on these concepts, the first version of prototype DOMs was designed and constructed at JPL. Two modules were deployed at ~ 1700 m depth at the South Pole in the 1996/1997 campaign in collaboration with the AMANDA group. The waveforms captured by the DOMs for AMANDA-triggered events are encouraging, revealing fine structures in the PMT signal with excellent resolution attainable only with DOMs. In this engineering test, some AMANDA-specific constraints impose severe data bandwidth and trigger rate limitations. Nevertheless, the data taken so far have already demonstrated the advantage of the new technology.

At the system level, the design focuses on array connectivity, power distribution, data acquisition network, universal time base, fault management, and quality assurance for array configurations within which the DOM and LSM are embedded. The realization of a km-scale detector system presents substantial challenges in deployment, maintenance, reliability, sensor performance, data acquisition, experimental control, and power distribution. Technical requirements are strongly coupled; an iterative optimization for the design process is anticipated.

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